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IMPROVED BRIDGE-TYPE DISTORTION METER

The bridge-type distortion meter is actually not a true bridge circuit but rather is a T-network with R, C, and L components. The popular conception of this circuit as a bridge has resulted from the fact that the circuit must be balanced to null in the manner common to bridges. The **bridged-T network,** which is the basis of a number of audio-frequency distortion meters described from time to time, is shown in Figure 1.

An audio-frequency signal which contains a fundamental frequency and several harmonics, such as might be derived from the output of an audio amplifier, is applied to the input terminals of the bridged-T network. This input voltage is designated E_1. The fundamental frequency will be balanced out, provided the constants L, C_1, C_2 and R are chosen properly, and little or no fundamental will be present in the output voltage E_2.

Since the circuit is adjusted to remove only the fundamental frequency, harmonic components pass through with little attenuation and constitute the greater part of the output voltage E_2. Terman[1] points out that the second harmonic, for example, will undergo only ½ db of attenuation when the circuit Q is 3. The ratio $(100E_2)/E_1$ thus expresses directly in percentage the total harmonic distortion. Note that this figure includes **all** harmonics, the 2nd, 3rd, etc., and no provision is made to appraise the distortion components separately.

In the bridged-T circuit, the two capacitors (C_1 and C_2) are equal in capacitance. These components must be matched closely. Choke L must

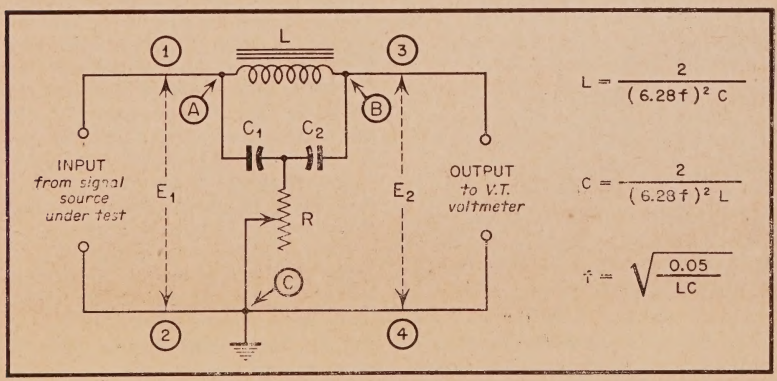

Fig. 1. Basic bridged-T network.

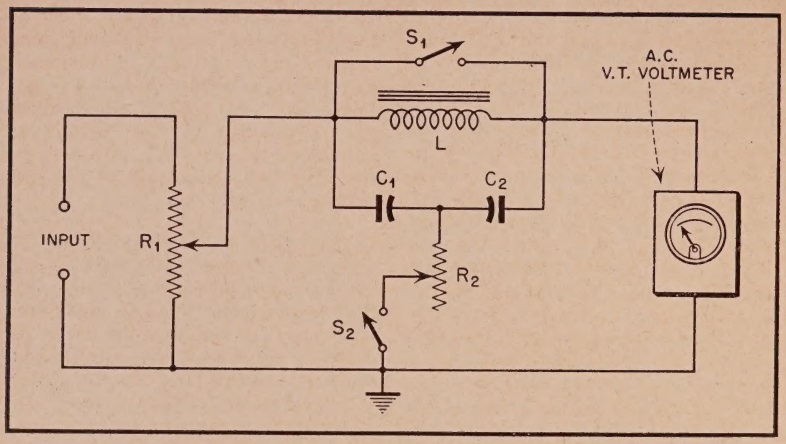

Fig. 2. Common distortion meter setup.

have the highest Q (ratio of X_L to R) obtainable in a commercial component of the required inductance.

In Figure 1 are given simplified equations for inductance of the choke, capacitance of the capacitors, and null frequency — each in terms of the other two. Inductance is given in henries, capacitance in farads, and frequency in cycles per second. From these equations, the electronic technician may determine the value of capacitors to be used with an available choke for a given null frequency, he may determine the value of choke required for use with a pair of closely-matched capacitors he already owns, or he may determine the null frequency which will be obtained with both choke and capacitors already in his possession. The variable resistor R, aids in sharpening and deepening the null obtained with the network. Once set for a given frequency, this control needs no further adjustment. For the usual run of audio testing between 20 and 20,000 cycles, R will have a total resistance value of 1 megohm.

The best way to operate the distortion meter would be to connect one a. c. vacuum tube voltmeter between points 1 and 2 (See Figure 1) to measure input voltage E_1, and a second v. t. voltmeter between points 3 and 4 to check output voltage. For reasons of economy, the two meter system seldom is possible to the experimenter or to the small laboratory with a limited instrument budget. The scheme usually employed with a single meter is illustrated in Figure 2. In this arrangement, R_1 is a suitable potentiometer or attenuator for adjusting input voltage E_1 to a prescribed reference level. In order to set to this level, switch S_1 is closed and S_2 is opened to remove the bridged-T network from the circuit and to connect the v. t. voltmeter directly to potentiometer R_1. Next, switch S_1 is opened and S_2 closed. This places the null network into the circuit and connects the meter to the output. Thus, by effectively removing and replacing

the null network, the v. t. voltmeter is caused to read first the total input voltage and then the harmonic distortion output voltage.

A second method of operating the setup is to employ a calibrated attenuator at R_1. With S_1 open and S_2 closed to insert the null network into the circuit, the small output voltage E_2 is read with the meter. Then; S_1 is closed and S_2 opened to remove the null network, and attenuator R_1 adjusted to bring the meter deflection to the same value as before. The final reading of the attenuator then is the level of the total harmonics in db below the combined input voltage E_1.

The second method has the disadvantage that an expensive, direct-reading, constant-impedance attenuator is required. An ordinary high-resistance potentiometer cannot be read closely enough at low-resistance settings. The first method has the disadvantage that the two readings are not made under identical conditions. In one instance, for example, the null network is switched into the circuit and the voltmeter is connected to the output. The equivalent circuit is shown in Figure 3B. When the null network is switched out of the circuit, the voltmeter alone is connected to the input potentiometer, as shown in Figure 3A. The potentiometer load thus is not identical in the two cases. This method of measurement does not approximate the ideal two meter method depicted in Figure 1.

The improved distortion meter circuit (See Figure 4) overcomes the shortcomings just mentioned by replacing the meter with an equivalent impedence network as the meter is switched from input to output. Thus, the null network is left in the circuit at all times; and although the meter is changed in position in the setup, the equivalent circuit of the meter is substituted when the meter leaves any portion of the circuit. This arrangement results in a constant load across the input potentiometer, R_1. Also, both input and output voltages are measured under identical circuit conditions, a situation which enhances the accuracy of distortion measurements.

In Figure 4, the equivalent meter networks are C_1-R_2 and C_4-R_4. In each of these identical series R-C combinations, capacitance and resistance values

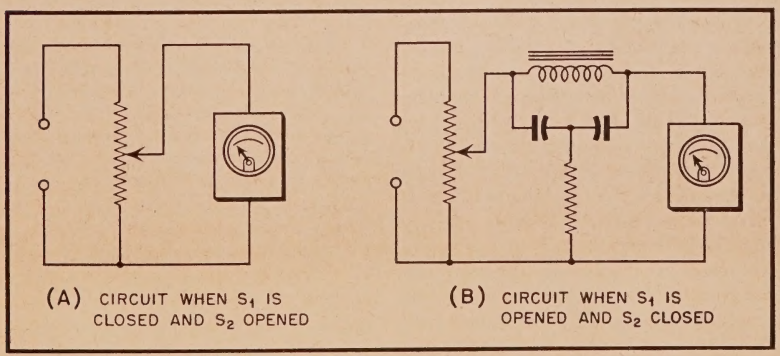

Fig. 3. Equivalent circuits in the two test positions.

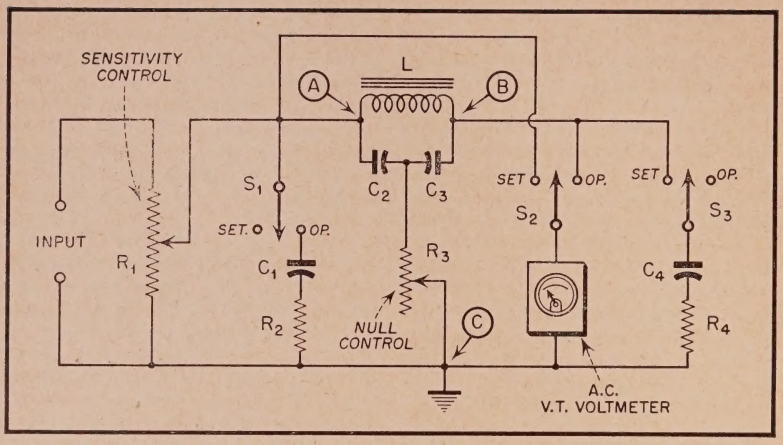

Fig. 4. Improved distortion meter circuit.

are those corresponding to the input C and R of the a. c. vacuum tube voltmeter employed. These values can be obtained from the meter manufacturer's literature. The Editors employed a Sylvania Type 221 Polymeter in their tests of this setup. The input constants of this instrument are 2.7 megohms resistance and 194 uufd. capacitance. C_1 and C_4 consequently each were made up to 194 uufds., and R_2 and R_4 each made 2.7 megohms.

Three single-pole, double-throw switch sections (S_1, S_2, and S_3) handle the meter switching. Actually, these three sections are combined in a single 3-pole, double-throw switch. When the switch is thrown to its SET position, the v. t. voltmeter is connected to the input portion of the circuit across the output terminals of sensitivity control R_1. The equivalent meter circuit, C_4-R_4, then automatically is connected in place of the meter across the output of the null network. The meter now may be used to read the input signal voltage which is set to a prescribed reference level by means of control R_1. After this setting is made, the switch is thrown to its OPERATE position. In this position, the meter is connected to the output terminals of the circuit to read harmonic voltage, and in its place the equivalent meter circuit C_1R_2 is switched across the sensitivity control. It may be seen readily that when the meter is moved from one portion of the circuit to another, it is replaced by its equivalent impedance.

Components given in the caption for Figure 4 have been chosen for a test frequency of 400 cycles per second. If distortion measurements are to be made at other frequencies, suitable values of L, C_2 and C_3 may be determined with the aid of the equations given in Figure 1. If distortion measurements are to be made regularly at a number of test frequencies, it will be advisable to construct a separate bridged-T network (L, C_2, C_3, R_3) for each frequency. These networks may be assembled in shield cans and provided with plugs at points

A, B, and C (See Figures 1 and 4). Capacitors C_2 and C_3 are seen to have odd values. Each unit is made up by connecting appropriate mica capacitors in parallel with a larger oil tubular unit to total the required capacitance. Actually, final adjustment of the capacitor values must be made with the desired signal frequency applied to the input of the instrument, because of manufacturer's tolarance in the inductance of the choke coil, L. Rheostat R_3 is provided with a slotted shaft for screwdriver adjustment, since this resistance need be set only during the initial adjustment of the instrument and occasionally thereafter to compensate for aging of components or during recalibrations.

The triple-pole, double-throw switch, S_1-S_2-S_3, must be of the anti-capacitance type or a good grade rotary selector switch with widely separated contacts. This is to prevent feedthrough of the test signal.

The distortion meter may be built up as a stationary instrument or the parts may be assembled and hooked up breadboard fashion whenever the setup is occasionally needed for bench use. The indicating a.c. vacuum tube voltmeter should have at least one low-reading scale. This is necessary because the input voltage obtained from some equipment under test will be quite low, making it impossible to read the still lower distortion voltage. Vacuum tube voltmeters with millivolt scales, such as Ballantine 300 series and Hewlett-Packard 400 series, are ideal for this application.

Initial Adjustments

After the distortion meter has been completed; (1) throw switch S_1-S_2-S_3 to its OPERATE position. (2) Set the meter to its 1-volt range. (3) Set sensitivity control R_1 for maximum signal. (4) Connect a low-distortion audio oscillator to the input terminals of the distortion meter and set the oscillator frequency to the null frequency of the bridged-T network. (5) Tune the oscillator above and below the null frequency value, noting that the meter deflection goes through a pronounced null dip at one setting of the oscillator dial. (6) Adjust rheostat R_3 for deepest null indication (that is, lowest voltage indication). Change the meter to a lower scale if necessary, in order to follow the dip. (7) If this setting of the oscillator dial is not the exact frequency desired (say, 400 or 1000 cycles), adjust the values of the capacitors C_2 and C_3 until null does occur at the proper frequency. After each capacitor change, re-set rheostat R_3 for improved null. (8) After all adjustments are completed, any residual voltage remaining at null will be due to distortion of the audio oscillator. To check this distortion, (a) throw switch S_1-S_2-S_3 to its SET position and adjust the oscillator output to give some convenient deflection of the meter, say 1 volt, when control R_1 is set for maximum signal. Record this voltage as E_1. (b) throw switch S_1-S_2-S_3 to its OPERATE position and note the lower reading. (c) rock the audio oscillator tuning back and forth for lowest reading (null) of the meter. (d) note the meter reading, switching to a lower voltage scale if necessary, and record this voltage as E_2. (e) determine the oscillator distortion percentage by dividing $100E_2$ by E_1. (9) Record this value and subtract it from any distortion percentage values obtained subsequently when using this oscillator in distortion measurements. (10) If other plug-in bridged-T networks are available for additional test

frequencies, repeat Steps 1 to 9 with each network in place in the circuit.

Use of the Distortion Meter

The distortion meter may be used for checking oscillators, and amplifiers. It undoubtedly will find most use by the audio technician and experimenter in checking total distortion of P. A. systems and playback units. The following test procedure should be followed. (1) Connect the low-distortion audio oscillator to the input of the amplifier under test. (2) Set the amplifier controls to the desired positions for the test. (3) Set the oscillator to the test frequency and advance the oscillator output to the desired amplifier-input signal level. (4) Set switch S_1-S_2-S_3 in the distortion meter to its SET position. (5) Set sensitivity control R_1 to its maximum signal position. (6) Connect the distortion meter input terminals to the output load device of the amplifier under test. (7) Set sensitivity control R_1 for a convenient reading of the meter. Record this voltage as E_1. (8) Throw switch S_1-S_2-S_3 to its OPERATE position, noting lower meter reading. Change the meter to a lower-voltage scale, if necessary, for accurate reading of the null. Tune the oscillator carefully for lowest dip in the meter reading. Record this voltage as E_2. (9) Determine the distortion percentage by dividing $100E_2$ by E_1. (10) For true distortion percentage, subtract from the value just calculated, the oscillator distortion percentage previously determined. (11) For a true appraisal of amplifier distortion characteristics, repeat the distortion measurements at various signal input levels and at various settings of the amplifier volume and tone controls. Also, repeat the entire test procedure at several frequencies.

When the output signal of the amplifier or oscillator under test is small, it will be necessary to connect a booster amplifier ahead of the distortion meter. Any such amplifier must itself have low distortion and, to this end, preferably should incorporate a large amount of corrective feedback. The distortion of this amplifier must be measured beforehand and this value subtracted from all distortion percentages obtained with the amplifier in the test setup.

LIST OF COMPONENTS

C_4, C_4—Selected equal to meter input capacitance (See Text)

C_2, C_3—0.301 ufd.

L—8 henries

R_1—25,000-ohm wirewound potentiometer

R_2, R_4—Selected equal to meter input resistance (See Text)

R_3—1-megohm potentiometer

S_1-S_2-S_3—3-pole, double-throw low-capacitance switch

REFERENCE

[1] Terman, F. E. Radio Engineer's Handbook (McGraw-Hill Book Co., N. Y.) 1st Edition. 5th Impression. pp. 944-945.

SUGGESTED SUPPLEMENTARY READING

Turner, Rufus P. A Compact Distortion Meter. Radio & Television News. November, 1948. p. 68.

C-D CAPACITOR. Distortion, Its Meaning and Measurement. January, 1949.

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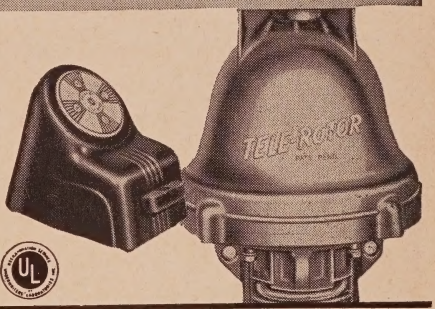

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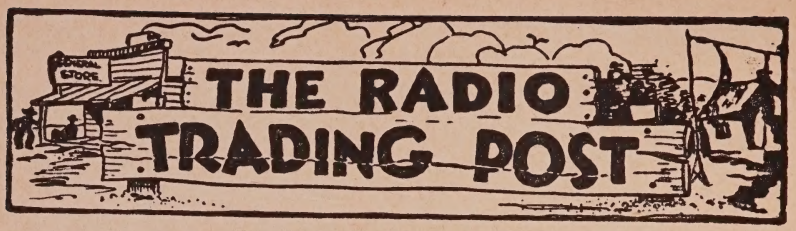

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FOR SALE OR SWAP—RCP model 447B VOM; NRI VTVM, 20,000 ohms per volt; NRI sig. gen., 100 kc. to 60 mc. Want Fundamentals for Eico Line, or what have you? Karl Nester, Van Meter, Pa.

FOR SALE—3-tube phono amplifier complete with tubes and speaker. Uses tube types 50L6, 12SQ7, and a 35Z5 GT/T. Priced at $7.50 for immediate sale. William Hintz, Rt. 4, Hutchinson, Minn.

FOR SALE—Zenith LP Cobra tone arm with cartridge, $5; RCA two channel wire recording head with separate erase and playback heads, erase coil, $5. James W. Meyer, RFD 4, Oregon Rd., Madison 5, Wis.

FOR SALE—Panadaptor, $65; S X 25, $70; RCA Rider Chanalyst, $75; Riders Manuals, 1 thru 14, $115; Precision E 400 with TV crystals, $125. All excellent. William M. Carroll, 710 Valley St., Maplewood, N. J.

WANTED—Co-axial TEE connectors. Designation Amphenol-83-1T, or Army-Navy M358. Advise availability and price. Adrian Van Keulen, Television Engineers, 1539 W. Harrison St., Chicago 7, Ill.

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WANTED—GE type G2AY audio oscillator, new or used. Jacques A. Kurtz, 642 East 23rd St., Brooklyn, N. Y.

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SELL OR TRADE—K&E Log-Log Duplex Vector Slide Rule, excellent and in orig. case, incl. inustr. manuals; Aero Digests, including directory copies, March '47 to current date. Need Sept., '50, and prior Radio & TV News, test equip. Robert G. Heinzelman, 4821 Coolidge Ave., Culver City, Calif.

FOR SALE—One series 912 Precision Electronic tube tester with full instructions; one DF series 965 Million tube tester with full instractions. Best offer, single or both. John W. Lezinsky, 174 Blaine St., Fairfield, Conn.

FOR SALE OR TRADE—Mercury II camera with case, shutter speed to 1/1000 of a sec., 35mm film and lens, 65 pic. on a standard 36 exposure roll, used only twice. Best offer takes. Stephen Barniak, 2426 Perot St., Philadelphia 30, Pa.

TRADE—Have Hickok tube checker, VOM, photocell, photo-electric relay and Handee electric drill. Would like tape recorder or what have you? M. R. Green, 38 Gautier Ave., Jersey City, New Jersey.

WANTED—Communications rec. in good or repairable condition. Phone and CW xmtr, 500 watts. Give price and cond. Cash or swap. J. J. Santonas, 14 Railroad Ave., Hammonton, N. J.

WANTED—Rider Manuals, vols. 11-20, in singles or all in one lot, reasonable. Ralph Giovannetti, 7 Hewitt St., Trenton, New Jersey.

WANTED—An FCC approved Citizens Band trans. and receiver. Give price. John Hickey, c/o Lew Bonn Co., 141-147 West 7th St., St. Paul 2, Minn.

SELL OR TRADE—Variable Inductor (32 mh similar to L&N type), 5" C.R. tube, portable radio, portable radio chassis, 4" speaker, parts bin. Want typewriter, camera, photo equip., back issues Electronics or IRE journal, or what have you? H. Galanty, 36 Montgomery Rd., Livingston, N. J.

BUY OR TRADE—Will buy or trade for test equipment. Send for my list. John Trowbridge, 655 W. 81st St., Chicago 20, Ill.

WANTED—One "University" No. 4A4 with or without units, or equivalent. Johnston's Radio Service, 378 Chestnut St., Oneonta, N. Y.

WANTED—Short wave rec. Any make or model. H. Latko, 1922 Dickens, Chicago, Ill.

SWAP—Universal 8mm camera and projector. Want Eico model 425-K scope or Heathkit No. 06. Also want NRI No. 1175A or 1175B comb. tester. Wm. J. Schwallier, 406 Crestview Dr., Henderson, Ky.

WANTED—Standard Relay Rack, open preferred but will ocnsider reasonably priced closed rack. Also PE-103 dynamotor. Stephan Kaufmann, 193 Main St., New Britain, Connecticut.

SWAP—10" TV with Mallory-DuMont front end, also all kinds of ham gear, for Panadaptor, wire recorder unit, any good surplus (ARC-1, ARC-3, "TS-" units, etc.) and Lab equip., or will pay top cash. Littell, Farhills Box 26, Dayton 9, Ohio.

FOR SALE—Model 76 Aerovox capacitor checker, never been used, $30; RC-60 Garard 78 rpm record changer in original carton, $35. Donald E. Grimwood, 317½ - 3rd Ave. East, Duluth, Minn.

FOR SALE—3" Espey TV set with all channel tuner, sell with or without tubes, includes 3KP4, fine shape. Also sell 50' of excellent FTR sheilded 300 ohm TV lead, and Superior multimeter. Peter Bedrosian, 2 Unicorn St., Newburyport, Massachusetts.

FOR SALE—Vomax 900; Precision E-200C; Simpson 260, roll top cabinet; all excellent. Best offer takes them all. Local buyer preferred. Wm. Dressler, 2611 Avenue I, Brooklyn, N. Y.

WANTED—One 10 watt amplifier; one 25 watt P.A. amplifier. No mike or speakers, just the amplifier. State price. Ryans Radio & TV, 15 Lincoln Ave., Havertown, Pa.

FOR SALE—RCA amplifier. 30 wall speakers, 1 radio-phono combination, 4 bell horn speakers, 1 desk mike, 1 floor mike. Used in industrial plant. Make offer. Troch, Main St., Spotswood, N. J.

FOR SALE—2 volt-ohm meters, 2 meg. and 10 meg., $5 ea.; vacuum tube volt-ohmeter, $35; Hickok tube tester and volt-ohmeter combined, $75. Also hard-to-get tubes. Cecil Morgan, Chipala Box 500, Marianna, Fla.

SELL OR SWAP—Precision 920 tube-tester and multi-checker in good condition; RCA 12" PM speaker perfect cond; inoperative all-wave German home receiver in a beautiful table-model cabinet. E. Lind, 686 Georgia Ave., Brooklyn, N. Y.

WANTED—German radio tubes, DL-11, DAF-11, DF-11, and DCH-11, or four bottoms (bases) of any of the above tubes. L. Andrews, 957 E. 3rd St., Erie 3, Pa.

WANTED—Test equip. 20,000 volt multitester, oscilloscope wide-band, RCA TV sweep generator. J. Bazewick, 3000 No. Christiana, Chicago 18, Ill.

TRADE—Zeiss-Ikon camera, compur shutter 1 to 250 speed, f4.5 Tessar lens, size 120, leather case. Want test instruments. Wilbur M. Dallas, 101 East Kentucky St., Anadarko, Okla.

FOR SALE—Will design and build electronic equipment to your specifications. Also will wire kits. Inquiries solicited. Paul Bateman, 619 W. 2nd, Emporia, Kan.

SWAP—Complete KW xmtr components, almost new. Want outboard motor and boat, or what have you? Bob Beard, Box 1115, Lancaster, Pa.

FOR SALE OR TRADE—1 each 1/3 and 1/2 h.p. Diehl two phase 60 cy. 220 volt a.c. ball bearing motors. Both $25, or will exchange for single phase motors. R. Bronson, 8426 - 169th Jamaica 3, N. Y.

FOR SALE—Precision 856T tester, A-1 condition, complete in hardwood carrying case. Leo Labassiere, 11 Gareau Ave., Ware, Mass.

SELL OR SWAP—Rider Manuals, 1 to 14, $50. Prefer to trade for test equipment. What have you? H. R. Holtz, 9208 Annapolis Rd., Philadelphia 14, Pa.

WANTED—Pilot 3" TV set. Give condition, price, and all particulars. Eugene Kon, 1575 Broadway, Buffalo 12, N. Y.

WANTED—Antenna for APN1 altimeter. State price. Paul Howcraft, 122 Bracewell Ave., No. Adams, Mass.

FOR SALE—Heathkit tube checker; Heath sig. gen.; Heath battery eliminator. All in good working condition. Duane Vaught, RFD 8, Bloomington, Ind.

FOR SALE—3 channel 7" TV console, built-in AM radio, has about 25 tubes in all, $25 f.o.b. Also TV receiving tubes and instructograph. Nick's Radio, Box 303 Waldwick, N. J.

TRADE—Craftsman 3 wheel bandsaw, perfect condition. Want sig. gen., or good VTVM. M. R. Grant, 2809 Poplar Ave., Springfield, Ill.

WANTED—VTVM, Eico, Heathkit, or Triplett, in working order. Also sig. tracer. Will pay cash. Must be reasonable. William Penn, 18 Pomander Walk, New York City, 25, New York.

FOR SALE—NRI condenser resistor tester and signal tracer. Both in good condition, $60 for both. William Sternkopf, 878 Jefferson Ave., Brooklyn 21, N. Y.

FOR SALE—Only radio & bicycye business in two counties. Well established and doing good business. Well balanced inventory, low rent in new building. Scott's Radio Service, Box 447, Shoshone, Idaho.

WANTED—Recording machine with overhead cutter. Prefer 16" lathe bed type. Will consider anything. Also want playback equipment and 16" transcriptions. Harvey Hy White, 1105 Waller Avenue, Winnepeg, Canada.

WANTED—Sprague Telomike condenser tester in good condition. Joseph Raisman, 1751 Georges Lane, Philadelphia 31, Pa.

FOR SALE—Model TE6 Tradio coin operated hotel radio, used one year; model TE6-8 Tradio-ette, beauty parlor coin operated radio with Telerex head-set for use under drier. Make offer. f.o.b. Middleburg. Modern Electric, 29 W. Market St., Middleburg, Pa.

SWAP—Eico 425 scope and 5 tube broadcast receiver. Both complete with tubes and almost new. Want S-53 or equiv. State age and cond. Jerry Golden, 109 Weequahic Ave., Newark, N. J.

FOR SALE—Hickok 203 VT meter, used very little, $75; Garrard RC 100 record changer in wood case. What have you? General Radio Service, 1203 Eckart St., Fort Wayne 5, Ind.

FOR SALE—G.E. portable radio, model 260. New storage battery, 6 tubes, 6 wave bands, like new condition, cost $85, sell for $35 f.o.b. $10 cash — balance c.o.d. M. A. Porter, 1709 N. Larrabee St., Chicago 14, Ill.

WANTED—Used tape or disc recorder. Must be reasonably priced and in good condition. W. K. Patterson, 104 Wentworth St., Charleston, S. C.

TRADE—Voigtlander 9 x 12cm camera, extension bellows, anastigist Skopar f4.5. Want Altec Lansing model 604 loud speaker. A. C. Wooldridge, 246 W. Upsal St., Apt. E 104, Philadelphia 19, Pa.

FOR SALE—Tape Recorder, Brush BK-403 broadcast model. High and low input impedances, 600 ohm output, built-in speaker, two speed for 30 and 60 minute duration standard reel, $100 f.o.b. C. K. Chrismon, Chief Engineer, WFLO, Farmville, Va.

SWAP—Have new Sylvania 131 three-inch oscilloscope, never used. Want TV set, 10" or larger, in operating condition or in need of repair. State condition. Will pay reasonable difference. Benjamin F. Shannon, Manteo, N. C.

FOR SALE—Rider Manuals, vols. 1, 3, 4, 6, 7, 9, 10, 11, 13, 14; G.E. 1 vol. 1939 to 1942; RCA 1 vol. 1923 to 1928 and 5 vols, 1933 to 1937. Also a large quantity of up to the minute factory Philco Service Manuals. $75 for the lot. M. J. Callaghan, Eastern Electric Co., 302 East 33 St., N. Y. 16, N. Y.

FOR SALE—Varitran V-1-M, excellent, $7.50; wire stripper, all wire sizes, $5; 2 Sparkes-Tarzian TV tuners w/o tubes, $5 ea.; 1 Transvision IF strip w/o tubes, $5; 2 oscillator VO-3-B, Amplifier Co. of Amer., excellent, $25 ea. Carver TV Service, 1748 E. 177 St., Bronx 60, N. Y.

SELL OR SWAP—Original transformers and chokes for UTC (PA series) 60W and Thordarson 120W amplifiers; Carter 355A genemotor. Best offer or? Want good 2-speed recording table and cutter, Riders No. 7 and up. Leibe Sound Service, Pleasant Valley, N. Y.

TRADE—Masco 25MPCN system; 120 camera f4.5; BC929 converted scope; wattmeter; TV tubes; TV tuner; 60 watt regulator; 7" 3 channel TV. Nicholas Denaro, 24 Cleveland Ave., Waldwick, New Jersey.

WANTED—Condenser, resistance, capacity tester. Must go to at least 1000 mfd. Will buy kits unassembled with instructions. Prefer EICO 950K. Also want instruction book on Hickok model PSG-15. Fenton Canfield, 86 Hampden Rd., Rochester 10, N. Y.

WANTED—Simpson 260 or 303 multi-tester and BC-946-B receiver in good shape. Have 5 tube Truetone (white) a.c. radio, 1/4" Gilbert electric drill, and a few meters. H. L. Ekas, 105 Glass Ave., Lexington, Ky.

FOR SALE—6-20 CM coaxial wavemeter, $50; RCA U.H.F. sig. gen., $100; 1500 MC generator, $10; SCR-518 altimeter (complete), $60. Also three radar transmitters: T26/APT-2, $20; T27/APT-3, $15; T85/APT-5, $30. Peter Dal Corobbo, 10441 Corliss Ave., Chicago 28, Ill.

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